AIR QUALITY ISSUES IN BRITISH COLUMBIA

Concord Environmental Corporation
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Prepared For The British Columbia Round Table On The Environment And The Economy

ROUND TABLE

PREFACE

"Air Quality Issues In British Columbia" was prepared by Concord Environmental at the request of the British Columbia Round Table on the Environment and the Economy. It is part of a series of background reports dealing with issues which Round Table considered important to the development of a sustainable development strategy in British Columbia. It is intended to provide information that will assist the dialogue between the Round Table and the public.

The Round Table has not endorsed the report. The information provided and conclusions reached in this document are those of the author.

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EXECUTIVE SUMMARY

Air Quality Issues In British Columbia

This background report focuses on the status of air quality in British Columbia, and identifies current and emerging issues

The author concludes that air quality problems are generally localized: ground-level ozone in the Lower Mainland, sulphur dioxide and other sulphur compounds in industrial centres, particulate matter and dust near sources of smoke, and acid deposition in the Strait of Georgia. Overall, air quality has not improved in recent years, and population and development pressures are expected to continue overtaking the impacts of improved pollution control technology.

The report raises questions about the availability of standards and policies to address some of the current problems. It identifies regional air management authorities as a potential solution to air quality problems in large airsheds such as the Lower Mainland, it points to a need for policies to deal with undeveloped areas of the Province, and identifies a need for air quality standards.

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SUMMARY

This discussion paper has been prepared for the British Columbia Round Table on The Environment and The Economy as one of a series of papers intended to guide thinking about the issues facing B.C. while planning for environmentally sustainable economic development. The paper focuses on air quality and air quality issues in the province and attempts to place these in the context of the deliberations of the Urban Development Sub-Committee of the Round Table's Core Group on Sustainable Development Strategy. This background paper has been written for the informed, general reader and is intended to provide information for the public consultation phase of the Round Table's proceedings. The content is the sole responsibility of the consultant.

The material has been developed from readily available documents, many of which are summaries of air quality or emissions over a number of years. People who are knowledgeable about air quality and air pollution management and research issues in B.C. at the municipal, provincial and federal government levels were interviewed to obtain their perspectives on these issues. This is not an exhaustive or comprehensive review of detailed air quality data and is, therefore, somewhat qualitative. It is intended to be an objective overview of current air quality in B.C., and it also attempts to assess emerging issues with possible implications for the near future.

Brief introductory information about the basis of air quality assessment and regulation in B.C. is followed by a summary of current air quality in B.C. with comparative data for Canadian urban areas. To address the question of whether current air quality is getting (or is likely to get) better or worse, trends in B.C. air quality over the past ten to twelve years are summarized. Relationships among air quality, emissions, land use and development, are discussed, attempting to show how these relationships will become more complex as urbanization increases in the province.

Overall, air quality in B.C. is not improving significantly, and in some areas and for some pollutants, is deteriorating. Improvements in technology and pollution control equipment are, generally, reducing unit emissions, but these reductions are being overtaken by increased population and development. The situation is expected to remain in this state for the next decades, as the balance between unit emission reduction and economic expansion is maintained. After that, deterioration will occur, without significant changes in technology or land use management.

No specific recommendations are offered, but the principal issues which arise from the review are defined. Some of the major issues are focused in a number of questions which the Round Table may wish to address:

- Do we need airshed ambient standards and target loadings to know when we are achieving sustainability?

- Do we need more up-to-date emission standards, and more comprehensive proponent data, so that proposed developments may be thoroughly assessed in the review process?

- Do we need regional air management authorities to deal with air quality management in large-scale airsheds?

- Do we have adequate processes and policies for dealing with current problems, such as wood waste burners and regional ozone, which may serve as models for the future?

- Should B.C. consider a strategy for preventing significant deterioration of existing air quality in areas of the province which are currently undeveloped or developing?

- Should B. C. lead the way in managing emissions which contribute to global problems, or should we participate as required in national programs?

1 INTRODUCTION TO AIR QUALITY ISSUES

Background. Air quality is intimately related to economic development by the location, concentration and type of activity. Urban development, whether industrial, commercial or residential, inevitably generates air pollution. Air quality impacts of such development are controlled or mitigated by choice of technology and density of development. Benchmarks for air quality, such as ambient air quality objectives, guidelines and standards, or for emission levels, such as emission control objectives, guidelines and standards, are used to evaluate the acceptability of existing impacts and those of proposed development. As urbanization expands, the customary benchmarks of acceptability become more difficult to apply and interpret, because of the complex interactions among emissions from an increasing variety and number of sources in large, built-up areas. Assessing sustainability will continue to rely on such benchmarks however, since they permit us to judge how close we are to unacceptable limits of environmental impact.

National Ambient Air Quality Objectives (NAAQO's) and provincial analogues have been developed for several levels of acceptability which define corresponding ranges of air quality: Maximum Desirable, Maximum Acceptable and Maximum Tolerable - the Desirable being the most stringent. The levels correspond roughly to the B.C. Level A, B, and C objectives, respectively. It must be remembered that not all objectives are designed to protect human health. The basis for an objective, the criteria upon which it is established, may include effects on vegetation, aquatic biota or materials, or nuisance factors such as odour or soiling. The expressed objective is usually based on the most stringent of these limiting criteria.

Physical measurements of contaminant concentrations in ambient air are used to determine how actual air quality compares with the objectives. Since not every place in the province can be monitored, it is clear that the placement of monitoring instruments must be highly selective. In fact, each of the classic journalistic questions - Who? What? When? Where? and Why? - must be answered in deciding how to monitor air quality. Special problems arise when specific emissions (Sulphur dioxide, for example) occur from a concentrated industrial location. Dispersed monitors cannot be assumed to be measuring the impact on the nearest residents unless specifically sited for this purpose.

B.C. Ministry of Environment, Greater Vancouver Regional District (GVRD) and individual industries all carry out monitoring programs for both ambient air and source emissions in the province. Nationally, Environment Canada operates the National Air Pollution Surveillance

(NAPS) network, with the cooperation of provincial and municipal agencies. The NAPS network is intended to characterize typical urban air quality to which the majority of residents of an urban area are exposed. This is the 'why' of the monitoring network and must be recognized when reported data and trends are interpreted. That is, NAPS does not purport to represent air quality everywhere in Canada. This precaution must be taken in interpreting data from any monitoring network or individual station.

The current B.C. provincial network consists of a large number of stations and instruments, some of which are operated as part of the NAPS network. GVRD also operates an extensive network, some stations of which are part of the NAPS network.

This paper summarizes some of the existing monitoring data from the above sources and attempts to define and clarify some of the current issues which are important for the Round Table to consider, especially in the context of interactions between land use planning and the environmental impacts of development.

2 CURRENT STATUS OF AIR QUALITY IN B.C.

The national picture. Air quality in urbanized areas of B.C. may be compared with urban air quality across the country by comparing data from the B.C. stations in the NAPS network with the rest of the network. The B.C. NAPS stations are located in GVRD (reported as "Vancouver" - 13 stations), Victoria, Prince George, Kamloops, Kelowna and Penticton.

Environment Canada has been reporting air quality status and trends based on NAPS data for many years. The NAPS reports cover the conventional pollutants [i.e., those for which formal objectives have been set: sulphur dioxide (SO_2), nitrogen dioxide (NO_2), carbon monoxide (CO), ozone (O_3) and suspended particulate matter (SPM or TSP)] and the additional parameters: lead and soiling index (or coefficient of haze, COH).

Five of the stations in the GVRD (in Vancouver and Burnaby) and the Victoria station are Class I, or comprehensively instrumented stations, which meet certain NAPS data reporting requirements (although currently the Victoria station measures only SO_2 and O_3). Long-term trends, which are discussed below, are analyzed only for the Class I stations by Environment Canada. Environment Canada's trend analysis for 1983 - 87 compares the performance of 16

of the largest urban areas, as represented by their NAPS station data. Table 1 depicts some of these comparisons qualitatively for GVRD and Victoria. For those wishing somewhat more detailed comparison, the following text provides a summary. Higher ranking in this summary means higher pollutant levels, hence poorer air quality.

GVRD and Victoria rank in the better half of the 16 major urban areas with respect to sulphur dioxide (exceeding the Prairie cities and London), and with respect to suspended particulate matter (near the mid-range, exceeding Halifax, which has the lowest levels in Canada). GVRD is in a large cluster of urban areas near the upper rank for annual average nitrogen dioxide level, whereas Victoria is in another cluster at a somewhat lower rank similar to Winnipeg, Hull and Saint John. GVRD is in the upper rank of Canadian cities respecting carbon monoxide average levels, whereas Victoria is near the mid-range. GVRD and Victoria are near the bottom rank of urban areas (along with Halifax) for average peak hourly ozone levels. In GVRD's case, this is consistent with the relatively high levels of nitrogen dioxide, and the relatively small amount of ozone precursor emissions in areas upwind of GVRD. Nitrogen oxides are emitted as a mixture of different chemical compounds, consisting mainly of nitric oxide (NO) and nitrogen dioxide (NO_2), represented as NO_x. The nitric oxide component of NO_x reacts with ozone, destroying it to produce nitrogen dioxide. Unfortunately, the enhanced nitrogen dioxide is then available to participate in further chemical reactions to elevate ozone production downwind.

The B.C. NAPS stations which are not Class I stations monitor a limited set of pollutants. The additional GVRD stations monitor mainly suspended particulate matter, and most met the Desirable objectives, with two exceptions. The Prince George station failed to meet either the annual or 24-hour Desirable objectives for suspended particulate matter, and the Kamloops station failed to meet the Desirable level for the 24-hour objective. The Kelowna and Penticton stations report ozone to the NAPS database; Kelowna exceeded the Desirable level for the 1-hour ozone objective.

Coefficient of Haze or Soiling Index is a measure of the soiling or darkening potential of fine airborne particles - it is not the same as visibility, however. There are no official objectives for this parameter, but it is a useful surrogate for airborne particulate matter concentration, because it can be measured semi-continuously so that it can be used in conjunction with the continuously monitored pollutant data. Of the major Canadian urban areas, Victoria has the

TABLE 1. COMPARISON OF GVRD AND VICTORIA AIR QUALITY WITH 14 OTHER CANADIAN URBAN AREAS

	Pollutant					
	SO2	NO2	CO	O3	TSP	COH
GVRD	Mid	High	High	Low	Mid/Low	Low/Mid
Victoria	Mid	Mid/Low	Mid	Low	Mid/Low	Low

Legend:

"Mid" signifies middle of the range of the 16 cities.
"Low" signifies the low end of the range (better air quality).
"High" signifies the high end of the range (worse air quality).

The comparison is for averages over the period 1978-87.

SO2 is sulphur dioxide;
NO2 is nitrogen dioxide;
CO is carbon monoxide;
O3 is ozone;
TSP is total suspended particulate matter;
COH is coefficient of haze (soiling index).

best performance respecting this measure. GVRD is in the better half of urban areas, ranking similarly to Calgary and Edmonton, exceeding Winnipeg (which is bettered only by Victoria).

The above comparison of B.C. NAPS data with the national database is varied, depending upon the pollutant. In some cases, GVRD air quality is better than for comparably-sized Canadian urban areas, and in other cases, it is similar. Victoria's air quality is generally better than other Canadian areas, but similar to those of comparable size. Generally speaking, with the exception of nitrogen dioxide, one or more of the Desirable objectives is exceeded at at least one station in B.C.; some stations exceed the Acceptable objectives for ozone and suspended particulate matter. Level C objectives are exceeded rarely, and only for ozone and particulate matter. This situation varies considerably from year to year as emission levels and meteorological conditions vary.

The picture within B.C. B.C. Pollution Control Objectives are similar to the federal NAAQO's, with some minor differences. Reports on the achievement of these objectives can be compared across reporting agencies (MOE, GVRD, Environment Canada) reasonably consistently.

The greater variety of station sites in the province outside of the cities allows a more comprehensive picture of air quality to be assembled. For example, data from stations in the Fraser Valley downwind of GVRD reflect the elevated levels of ozone which are produced by the chemical reactions with sunlight of pollutants emitted from the more urbanized area. This phenomenon is not shown by the NAPS network data alone. Similarly, the more broadly based provincial network permits the impacts of built-up or industrialized areas which are not yet urban to be identified. These impacts are important to assess as potential effects of urban development in the province.

The principal pollutants in consideration of air quality outside of GVRD are sulphur dioxide, suspended particulate matter, ozone and reduced sulphur compounds. The latter is a mixture of chemical compounds which contains sulphur in the form of hydrogen sulphide (H_2S), methyl mercaptan, dimethyl sulphide and dimethyl disulphide. This group taken collectively is referred to as total reduced sulphur (TRS). These compounds are characterized by their offensive odours at very low concentrations, and their principal impact at such concentrations

is nuisance, rather than serious health impairment. The principal sources of these pollutants are as follows.

SO_2:	combustion of sulphur-containing streams in chemical pulping; metal smelting; sour gas processing; fuel oil burning; oil refining; cement manufacturing
SPM:	wood waste & slash burning; mining & smelting; wood fuel burning
Ozone (O_3):	photochemical reactions (sunlight-driven) of nitrogen oxides (NO_x) and volatile organic compounds (VOC's)
TRS:	fugitive emissions from chemical wood pulping; oil refining; sour gas processing.

Table 2 summarizes the status of air quality respecting these parameters by qualitative evaluations relative to air quality objectives. More detailed information is provided below.

The highest percentage of exceedances of objectives occurs for TRS (expressed as equivalent quantity of hydrogen sulphide, H_2S). Both 1-hour and 24 - hour objectives are frequently exceeded, primarily at stations in Prince George and Castlegar. Exceeding the 1-hour Level B objective for TRS would lead to detectable odour, and to probable odour detectability when the Level A objective is exceeded, because of the way in which the human nose responds to odorous substances (i.e., by detecting very short-term excursions of contaminant concentration).

Sulphur dioxide exceedances have not been as numerous as for H_2S, but, nonetheless, they have been appreciable. The exceedences for SO_2 have occurred primarily at Port Alice and to a lesser degree at several sites near mining and smelting facilities in the interior (Trail / Kimberley).

High ozone levels may occur in the summer, when the temperature and amount of sunlight promote the chemical reactions that produce it from the mixture of nitrogen oxides and hydrocarbons (VOC) emitted in urban areas - principally from motor vehicles. The most frequent exceedances of the 1-hour Level B ozone objective have occurred in the eastern part of GVRD and further east in the Lower Fraser Valley. Ozone is clearly a regional problem, extending beyond GVRD across several regional districts and municipalities. The fact that the precursor pollutants are emitted primarily in the heavily urbanized area to the west of the

TABLE 2. CURRENT B.C. AIR QUALITY COMPARED WITH AIR QUALITY OBJECTIVES

Region	Pollutant					
	SO2	NO2	CO	O3	TSP/Dust	TRS
GVRD	G	G	F	F (P)	G-F (P)	**
Lower Mainland	G	G	**	F-P	G-F	F (P)
Vancouver Island	G-P	**	**	G	G-F (P)	F (P)
Southern Interior	G	**	**	G-F	G-F (P)	F (P)
Kootenay	F-P	**	**	**	G-F	F-P
Northern	G-F	**	**	**	G-F (P)	F-P

LEGEND: The following abbreviations refer generally to levels of air quality as shown in Figure 1. Assessment is subjective and qualitative.

G = Good (Level A generally not exceeded).
F = Fair (Level A frequently or occasionally exceeded, but not Level B).
P = Poor (Level B frequently or occasionally exceeded, but not Level C).
VP = Very Poor (Level C exceeded. This hardly ever occurs for any parameter monitored).

SO2 = sulphur dioxide
NO2 = nitrogen dioxide
CO = carbon monoxide
O3 = ozone
TSP / Dust = total suspended particulate matter / dustfall
TRS = total reduced sulphur (hydrogen sulphide)
** = not monitored in the region.
( ) = Occasional exceedances

affected areas underscores the importance of the interplay between urban planning and large-scale pollution control strategies.

As a general comment, ozone levels in the Lower Fraser Valley exceed the Maximum Acceptable objective from time to time, and the exceedances extend far up the Fraser Valley into the interior, indicating cause for action. However the present situation in the Lower Fraser Valley is predicted to remain about as it is - neither worsening nor improving - over the next twenty years, unless there are significant changes in transportation technology and land use patterns. It would undoubtedly deteriorate after that period as a result of expanded development.

The Air Quality Index (AQI), which takes into account the major pollutants, is available historically only for GVRD. Prince George has recently developed an AQI (for TRS), and other B.C. cities are likely to have one soon (e.g., Kelowna). Between 1986 and 1989, GVRD's AQI exceeded 50 (i.e., was in the Poor Range) on 80 occasions, 74 of these in 1988. The AQI at the five stations in the GVRD where it is calculated is typically in the Good Range (reading less than 26) at least 97% of the time. The major contributors to AQI values which are greater than 25 are carbon monoxide (in downtown Vancouver) and ozone (in areas outside the downtown core). Figure 1 shows the relationship between the AQI and the ambient air quality objectives.

In summary, air quality objectives for several pollutants are more frequently exceeded in areas of the province outside of the large urban centres. One of the principal reasons for this is the placement of the monitoring stations in these areas to monitor the impacts of specific point sources, rather than to characterize general air quality. In fact, most major point sources of emissions are located outside of urban areas.

3 TRENDS IN B.C. AIR QUALITY

The previous sections have indicated the current or recent status of air quality in the province, based on comparisons with air quality objectives. An important question is whether air quality is getting better or worse, either generally or with respect to some pollutants. A number of trend analyses have been published - for GVRD, B.C. and Canada - which have been referenced in the bibliography.

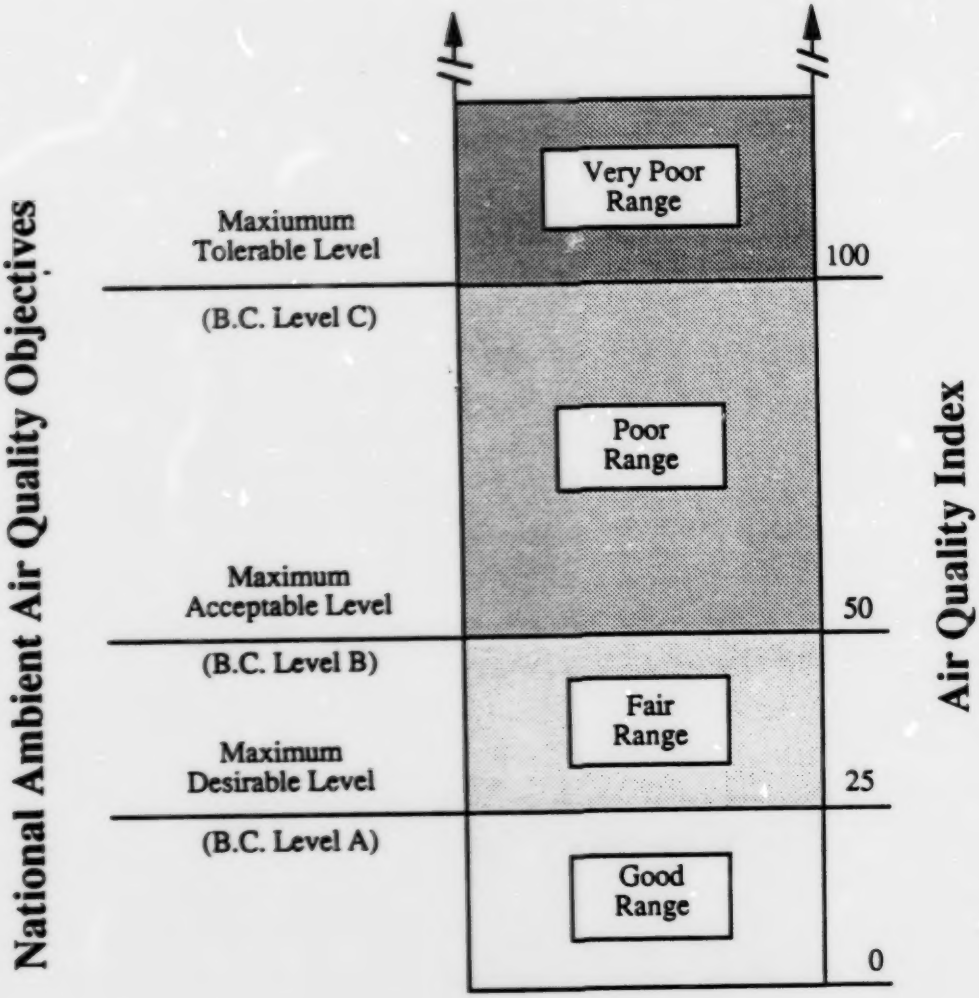


Figure 1. Air Quality Index - Objectives Relationship

Table 3 shows qualitative trends extracted from available air quality data summaries. The following text presents this information in more detail.

In GVRD, the only pollutants for which clear downward trends can be demonstrated over the past ten to twelve years are suspended particulate matter and sulphur dioxide, judged by the annual mean concentrations. Exceedances of the Level B objectives for particulate matter continue to occur episodically at stations along the Fraser River, and the total number of exceedances did not change significantly between 1986 and 1989. The Level B objective for sulphur dioxide was last exceeded in 1985, and Level A, in 1987. For carbon monoxide, nitrogen dioxide and ozone, there are no clear trends over the past 10 to 12 years. That is, for both mean concentrations and exceedances, there appears to be neither improvement nor degradation, at least as judged by mathematical analysis.

A particularly striking example of the merit of careful analysis and of not jumping to conclusions on the basis of limited air quality data is the situation with regard to ozone in GVRD. Between 1978 and 1987, the air quality data indicated that the number of exceedances of the 1-hour Level B objective had declined markedly and might have led to the conclusion that the ozone problem had been solved. The summer of 1988, however, was very bad for air pollution across Canada. The number and geographical extent of ozone Level B exceedances in the GVRD network increased abruptly in 1988 to near historical highs. 1989 was again somewhat better, but it remained clear, especially when ozone concentrations in the Fraser Valley downwind of GVRD were taken into consideration, that the apparent trend of the mid-1980's was produced by random occurrences of favourable meteorological conditions. Computer modelling carried out for the GVRD Air Management Plan Stage 1 indicated that with the current and predicted future emissions of ozone precursor compounds, there was reason to believe that historically high levels of ozone could recur, and the experience of 1988 bore that out. Predictions are that the combination of increased level of development in GVRD (hence potential emissions) with better technology (especially automobiles) will produce air quality which is similar to that over the past 10 or more years. That is, continued exceedances of the Level B and (occasionally) C objectives for ozone are expected over the next twenty years, unless dramatic emission reduction measures are implemented.

Ozone exceedances in the Lower Fraser Valley in the summer of 1987 provide a good example of what may be expected in the future in areas downwind of GVRD. In that year, no GVRD

TABLE 3. TRENDS IN B.C. AIR QUALITY

Time Base	Pollutant											
	Sulphur Dioxide		Nitrogen Dioxide		Carbon Monoxide		Ozone		TSP / Dust		Reduced Sulphur	
	GVRD	BC	GVRD	BC	GVRD	BC	GVRD	BC	GVRD	BC	GVRD	BC
Annual mean	SAME	INCR	SAME	SAME	DECR	***	SAME	SAME	DECR	SAME	***	SAME
Annual Exceedances:												
Level A	SAME	SAME	SAME	***	***	***	***	***	DECR	SAME	***	***
Level B	NONE	INCR	NONE	***	***	***	NONE	NONE	NONE	SAME	***	***
24-Hour Exceedances:												
Level A	SAME	SAME	***	***	SAME*	***	***	***	***	***	***	SAME
Level B	NONE	SAME	NONE	***	NONE*	***	***	***	DECR	SAME	***	SAME
1-Hour Exceedances:												
Level A	SAME	SAME	***	***	SAME	***	SAME	SAME	***	***	***	SAME
Level B	DECR	SAME	NONE	***	NONE	***	SAME	SAME	***	***	***	SAME

LEGEND: Subjective and qualitative assessment based on available air quality data summaries over the past 8 to 10 years.

*** = No applicable objective or no monitoring data.
SAME = No significant changes over the period.
INCR = Qualitative increasing trend over the period.
DECR = Qualitative decreasing trend over the period.
NONE = No significant frequency of exceedances.
* = 8-hour Average.
GVRD = Greater Vancouver Regional District.
BC = British Columbia outside of GVRD.

station experienced more than five exceedances of the Level B ozone objective, but four stations in the Fraser Valley did. It is expected that the emissions of ozone precursors (particularly NO_x) will increase in Vancouver, and as urban development spreads further into the Fraser Valley east of Vancouver, emissions of precursors will increase approximately in proportion to population. These emissions combined with the background ozone due to emissions in GVRD and with the higher summer temperatures further inland will very likely lead to exceedances of the ozone objectives extending further and further into the interior. It should be noted that researchers at the University of British Columbia have estimated that current, annual crop losses in the Fraser Valley due to ozone damage may be several million dollars. Any increase in ozone levels will increase this cost. Kelowna, as well, is already experiencing exceedances of the 24-hour Level B objective and the 1-hour Level A objective.

Outside of GVRD, the only long-term downward trend in pollutant concentrations is for suspended particulate matter. Two other major pollutants of concern in these areas of the province - sulphur dioxide and reduced sulphur - had not indicated major trends (up or down) between 1976 and 1987, although the annual average value in 1982 for reduced sulphur (hydrogen sulphide) was 36% lower than in 1978. Hydrogen sulphide did not exhibit significant change between 1983 and 1987, either in annual mean or number of exceedances of objectives. If the Port Alice data, which contributed to an increase in annual mean and frequency of exceedances, were removed from consideration, sulphur dioxide would have exhibited a similar pattern for this period (1983-87). The status of both hydrogen sulphide and sulphur dioxide exceedances should be changing currently as a result of upgrades to air pollution control systems, especially in the forest products industry, but it will be several years before the potential improvements are realized.

The decrease in suspended particulate matter levels has resulted, in part, from concerted efforts to control dust and smoke emissions in the forest products industry. This is particularly evident in the improving technology for wood waste combustion in beehive burners, for which combustion modifications or conversion to "smokeless" burners have greatly reduced emission factors. A trend in the recovery of wood waste heating values, either in on-site power boilers or in regional power production or co-generation systems, will further reduce emissions of particles. An example of this trend is a current proposal to replace six beehive burners in the Williams Lake area with a single, wood-fired electrical power station, which would consume the waste currently burned in the less efficient beehive burners. This project is estimated to

reduce the emissions of particulate matter in the airshed by a factor of about ten. Several regional offices of the Ministry of Environment identified this issue of wood waste energy recovery as their most significant, eventually resulting, ideally, in the elimination of all of the more than 100 beehive burners currently operating under permit in the province. The more efficient recovery of the wood waste heating value will result, as well, in lower carbon monoxide emissions.

In summary, current air quality problems in B.C. are generally localized in nature, although the ozone situation in the Lower Fraser Valley is a regional problem. B.C.'s problems are also not as severe as those of southern Ontario (and eastern Canada, generally), nor do they approach those of southern California (and many other areas of the U.S.). The density of industrial and residential development in the Lower Fraser Valley has not reached the levels of the more heavily polluted areas with which it may be compared, and the relatively low average temperature and intensity of sunlight associated with B.C.'s northern latitude discourage intense smog formation.

4 ECONOMIC DEVELOPMENT / AIR QUALITY RELATIONSHIPS

As pointed out in the Introduction, there are inevitable connections among development, land use, emissions and air quality. Detailed emission inventories have been developed for GVRD and the rest of B.C., as well as for all of Canada. Air quality is determined by the sum of emissions into a given volume of air and therefore depends on the density of emission sources, that is, the level of development. Land use also affects air quality not only by determining the density of development, but also by determining transportation routes and modes by which goods and people are moved from residences to the centres of employment. In GVRD, for example, motor vehicles are the major source of several of the main pollutants, so that the location of routes and traffic densities clearly influence the concentrations of contaminants in the nearby air. On a larger scale, for example, as discussed above for ozone, urban development and its attendant emissions from vehicles may influence air quality many kilometres away.

Existing emission inventories do not completely describe all sources of emissions in the province, since they tend to focus on point sources which are permitted under the Waste

Management Act. An illustrative example can be taken from GVRD data, where both point (permitted) and area sources, such as motor vehicle emissions, road dust and construction emissions, have been inventoried. Figure 2 shows the provincial point source inventory for the major pollutants, by geographic region, including GVRD. Figure 3 shows the GVRD data for the same year, but including both point and area sources. It is clear from these graphics that in urban areas, the area source emissions may far exceed those from point sources. As other regions of the province urbanize, this phenomenon will spread. That is, as urbanization spreads, industrial point sources, which are more easily controlled, in principle, by traditional permitting conditions and enforcement become relatively less of a problem. This is also true as heavy industry is replaced by service or knowledge-based industries. At the same time, transportation, for example, which is more difficult to control except by land use regulation, becomes proportionately a greater contributor to emissions.

Figure 4 summarizes the total provincial emissions of the conventional air pollutants by industrial sector. This figure covers only emissions from point sources permitted under the Waste Management Act.

Emissions of "greenhouse" gases will be important in evaluating environmentally sustainable economic development internationally. A recent inventory for B.C. of one of these gases, carbon dioxide (CO_2), indicates that about 35% of man-made CO_2 emissions in the province come from industrial stationary (point) sources, of which about 80% (or 30% of the total) are from the forest products sector. When CO_2 emissions from pulp and paper, prescribed burning (slash and fire control) and the wood products industries are combined, the forestry-related contribution to the total is about 40%. Motor vehicles and solid waste disposal together contribute about 25% of total CO_2 emissions. B.C. emissions of CO_2 are about 13% of the national total, just about proportional to population. Existing inventories do not include natural sources of CO_2, such as forest fires.

In summary, the information in the foregoing sections implies that there is a significant probability that restrictions would have to be placed on new or expanded development because of limited carrying capacity of the atmosphere.

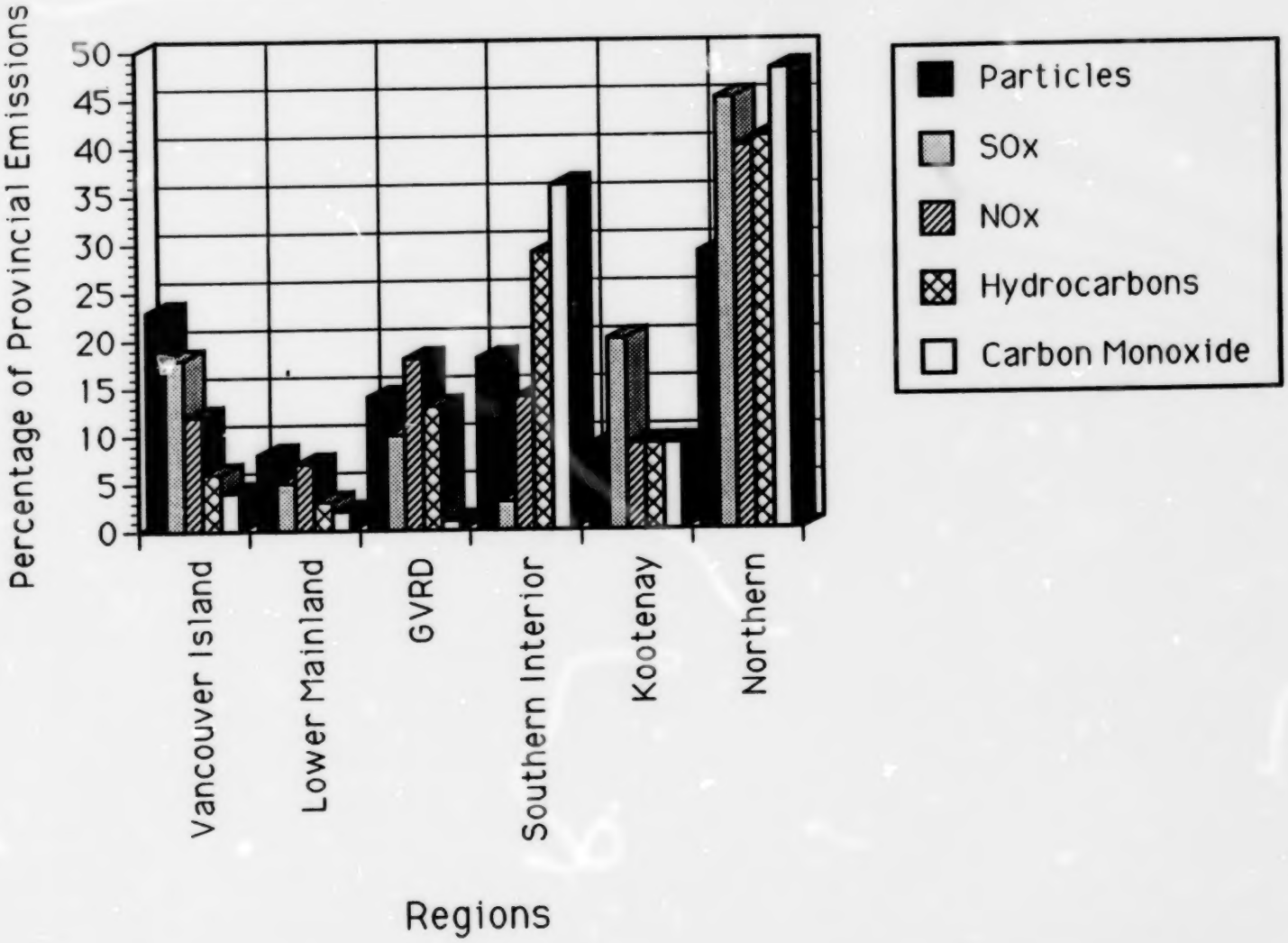


Figure 2. Provincial Point Source Emissions for 1985

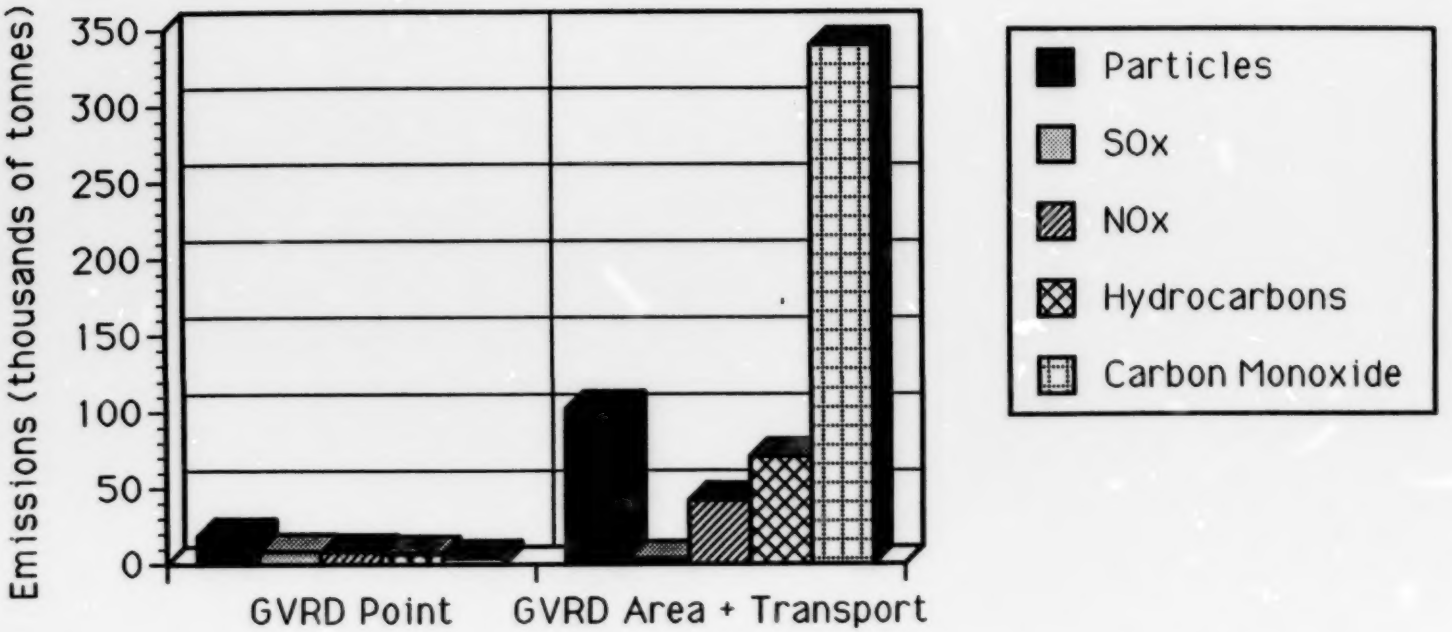
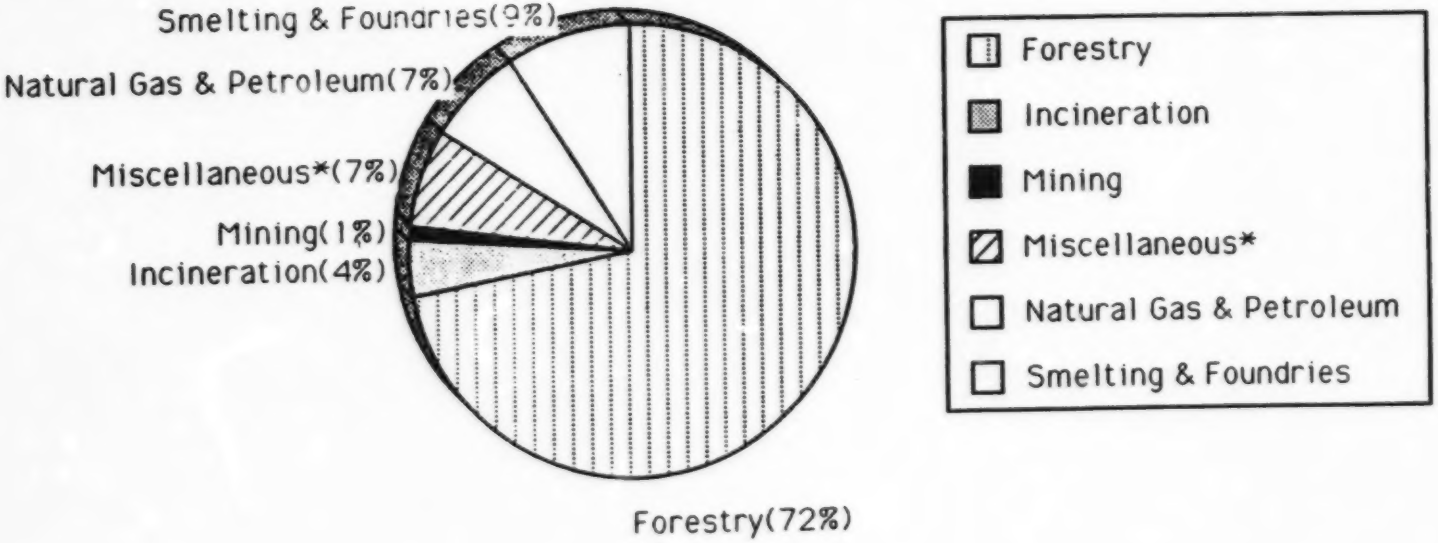


Figure 3. GVRD Emissions for 1985 - Point Sources and Total of Area and Transport Sources



* Includes Agriculture, Chemical, Food Processing, Utilities and others.
** Total 1985 point source emissions of particles, SOx, NOx, hydrocarbons and carbon monoxide.

Figure 4. Total Emissions** (outside GVRD) by Sector

5 CURRENT AND EMERGING AIR QUALITY ISSUES

A number of current and anticipated air quality issues have been expressed by people interviewed for this paper, and others have been described in the literature or implied by available data for B.C. The following list of potential issues is given in point form and is described more fully in the text which follows. These issues are divided into the categories air pollutant-specificic issues and general air quality management issues. The list is not ranked.

Air pollutant - specific issues:

- **Smoke (or airborne particulate matter) management** - slash burning, wood waste burning, residential wood fuel.
- **Visibility**
- **Long-range transport of air pollutants** - regional/transboundary ozone and acidic deposition.
- **Airborne toxic substances**
- Issues of enhanced global sustainability for the long-term such as **global warming** .

General air quality management issues:

- **Multiple-industry development** in smaller urban centres.
- **Airshed management** (e.g., Prince George, GVRD and Lower Fraser Valley) and the related issue: **regional pollution control and planning.**
- Development of up-to-date **emission objectives** and **air quality objectives**
- Development of **monitoring strategies** and **indices of environmental quality**.
- **Air quality modelling** in B.C.

Smoke (or air borne particulate) management. The most often mentioned issue by those involved in air pollution control and research in B.C. was smoke management. By this is meant control of the variety of sources which produce particulate emissions as a result of incomplete combustion of fuel. The principal sources have been noted above. This issue comprises both fine particle emissions which may impair human respiratory health and a

combination of coarse and fine particles which impair visibility. Both health and visibility are important values to residents of B.C. GVRD points out that clear air is a major tourism value, as well. With more stringent controls on the industrial sources of smoke emissions - wood waste burners and slash burning - already advancing, and more projects being proposed to use the wood waste materials more efficiently (power production, etc.), this sector will contribute less to airborne particle loadings in the future. The overriding issue in the future will probably become the contribution of all combustion sources to global effects, such as "greenhouse" gas production (see below).

Visibility. Increasing urbanization leads to increasing atmospheric loadings of fine particles, which are produced by transportation and other use of fuels, as well as industrial processes. Fine particles are more efficient reducers of visibility than large particles, because they are more effective light scatterers. Visibility reduction has also been shown to be related to fine particle loadings which are correlated with human respiratory impairment. That is, the impact is not just visual, it is also related to health impacts. The fine particle haze which is produced as a component of sunlight-induced smog is associated with airborne acidic particles and oxidants (e.g., ozone). In fact, visibility reduction may be one of the best indicators of overall air quality deterioration. Visibility studies have been carried out in B.C. from a research point of view, but objectives have not been developed. (Note GVRD's "invisible air strategy" as expressed in *Choosing Our Future*.)

Long-range transport of air pollutants. The transport of air pollutants from one region to another, on which they impact, is known as long-range transport (of air pollutants), or LRTAP. LRTAP issues in B.C. have to do with transport of oxidant and other air pollution up the Fraser Valley from the urbanized areas in the Fraser delta and with transport of pollutants from industrialized and urbanized areas of the adjacent U.S. into southern B.C. Preliminary analysis has indicated that most of the oxidant pollution which appears in GVRD and immediately downwind arises from local emissions, but more detailed analysis may show otherwise, since about one-third of the emissions into the Lower Fraser Valley airshed are emitted in the U.S. Measurements of acidic deposition (acid rain) in B.C. indicate that elevated levels of sulphur deposition (in the form of sulphate) occur over the Strait of Georgia and the North Shore. This may be due to locally-generated sulphur emissions (from refineries, pulp and paper plants and fuel oil burning), or sulphur emissions from refineries and other industrial sources in Washington State may be implicated. There appear to be insufficient data at present

to evaluate this situation objectively. Soil and lake sensitivity maps which have been developed for B.C. indicate that the coast (from the Sunshine Coast to Prince Rupert) and certain areas on the west coast of Vancouver Island and in the area of Chilliwack are sensitive to acidic deposition. The significance of this situation needs to be evaluated. The issue of whether lakes, fisheries and forests in this area are at risk from the observed levels of deposition has not been addressed.

Airborne toxic chemicals include a wide variety of industrial and commercial chemicals which are usually present in small or trace amounts. These chemicals, also called hazardous air pollutants, are of concern because their mode of action is not acute (immediate), and their effects may not be detectable until years after exposure. It appears that the number of such chemicals which is of current concern in B.C. is small, because of the relatively low level of chemical industry in the province. As petrochemical plants and similar facilities are proposed as part of the province's economic diversification, and as vehicle emissions increase with population, there may be cause for concern in the future. The current amendments to the U.S. Clean Air Act identify 189 candidate chemicals as hazardous air pollutants which must be assessed in existing emissions and in proposed projects. It appears that a very few of these chemicals may be present in situations which may be of concern in B.C. - the challenge is to identify those which are true hazards and to estimate their risks, so that realistic impact assessments can be carried out. It is suggested that this issue is not a major sustainability issue, but it ought to play a role in directing development from the perspective of possible human health impacts.

Emissions to the atmosphere which impact on global sustainability, such as the "greenhouse" gases which may lead to **global warming**, may be the overriding issue which influences consideration of sustainability in B.C. If current scientific predictions are correct, the effects of increasing concentrations of the gases carbon dioxide, methane, nitrous oxide, chlorofluorocarbons, and so on, in the atmosphere would have significant impacts on B.C., by climate alteration and sea level rise. International protocols to limit carbon dioxide emissions (as well as nitrogen oxide emissions), if implemented, would require B.C. to participate by, presumably, reducing its share of emissions. This issue is addressed more fully in a companion background paper on "Transboundary Issues".

B.C.'s electrical power is currently produced almost exclusively by hydroelectric facilities,

with low emissions of combustion gases such as carbon dioxide. Current strategy in B.C., however, is to diversify power production by encouraging independent power producers to develop regionally-based facilities using resources which make sense locally, such as wood waste, to generate power for the provincial grid. This strategy, along with conservation, removes part of the pressure from hydroelectric development for increased power capacity, which is necessary to support industrial, commercial and residential expansion. The alternative power sources tend to use fossil fuels or biomass (principally wood or coal, but also sewage and industrial process sludges), which alleviates the need to dedicate large areas of land to hydro facilities, but in exchange produces emissions of combustion products, including nitrogen oxides and carbon dioxide. The impacts of currently proposed facilities need to be seen in the context of overall air quality management, both now and in the future. The net effect on sustainability of the alternate environmental impacts is not clear at present. Power development policy is perhaps the more important issue.

Future development in the province which promotes power production or industrial processes emitting combustion or other gases implicated in the "greenhouse" effect could be significantly constrained. Carbon dioxide and nitrogen oxides are also produced by vehicles which burn fossil fuels, so that this sector would also be constrained. Although not traditionally treated as air pollution or as an air quality issue, emissions which contribute to potential global warming are likely to be the most important future issue for all jurisdictions, because of their intimate connection with energy production throughout the economy. Focusing on this issue would guide air pollution and air quality management with respect to other main pollutants, as well.

Multiple-industry development. As areas of the province whose economies are now dominated by a single industry, or a small number of industries, develop and diversify, air quality impacts will become more complex and more difficult to monitor. Traditional focus on point sources may not be sufficient to regulate urbanizing and diversifying regions. Development strategy as it relates to air quality will need to recognize emission contributions from a variety and number of sources in a region or airshed - as well as the more complex mixture of pollutants. In fact, in order to prevent overloading of an airshed with multiple contaminants, development decisions may have to prescribe and allocate permissible airshed use. This approach is already well-established in the U.S. (and re-affirmed under the recently-revised Clean Air Act) and is part of Ontario's Clean Air Program proposals. This issue is not necessarily related significantly to ecological sustainability, but rather to human health and

welfare, at least with regard to air quality. Deposition of airborne toxic substances may impact aquatic and terrestrial resources, but there is little evidence on this subject.

Airshed management. The previous issues have all alluded to the need in future to address air quality on a broad scale, and the airshed concept provides that context. By analogy with watershed management, which is better known, airshed management addresses all of the sources of emission into the air above a geographic area, within which topography and meteorological conditions constrain effective dispersion of pollutants. An airshed may be thought of as a geographic area over which the air emission sources contribute to the contamination of a common air mass. Existing and proposed sources are considered with respect to their cumulative impacts on air quality (or total emissions or total atmospheric loadings, etc.). Once the capacity of the airshed for a certain pollutant or group of pollutants has been reached, or is predicted to be reached with the addition of a project, emission permits take such constraints into account. The challenge is to determine airshed capacity for pollutants. Benchmarks, such as ambient air quality objectives or emission objectives, taking into account the carrying capacity of any airshed, need to be developed. The jurisdictional authority for management of airshed-wide air quality may need to extend beyond the boundaries of existing regional districts and municipalities - this would require the province to address issue-specific, extra-regional management authority. Airshed management also implies land use planning and management, if it is to be most effective.

Emission and air quality objectives. The need for up-to-date benchmarks for evaluating air quality, especially in the context of airshed management, has been pointed out above. Just as importantly, the regulatory framework needs to take into account the increasing complexity of air quality impact assessment as the variety and geographic distribution of emission sources develop. The establishment of appropriate objectives to control immediate effects and to help define sustainability will influence both impact assessments and **monitoring strategies**. Future regulatory strategy would address, as well, whether or in what form **indices of environmental quality** may play a role. The tendency of industrial development in B.C. to take place in areas with relatively poor dispersion characteristics (river and mountain valleys or sheltered coastal areas) means that realistic air quality impact assessment requires the use of **air quality models** which are capable of handling the complex meteorological conditions in these areas. Model predictions are only semi-quantitative estimates of expected air quality, and care must be taken to cover the conditions which are likely to prevail at the site of the emission.

British Columbia has a number of airsheds because of the complex terrain created by the many mountain ranges and river valleys, as well as the seacoast. One of the challenges to air quality modelling in B.C. is to treat this complex terrain meaningfully. It is technically difficult and the problem has not been solved satisfactorily. This is one of the reasons why B.C. does not have an explicit set of regulatory models which are specified for use in air quality modelling in the province. The suite of models developed by the U.S. Environmental Protection Agency is normally used for air quality modelling in B.C.

Conclusion. The above issue summaries are intended to indicate that considerations of air quality in planning for environmental sustainability must develop a broader perspective than the traditional emphasis on control of individual conventional or criteria pollutants. The ecological system interactions, which are influenced by human activity, are very complex and not yet at all well understood. Since we do not know all of the important factors (the variables in ecosystem models), we cannot presume to know how economic development really affects environmental sustainability. This fact is apparent in the current controversy within the scientific community about how the atmosphere will respond to increased concentrations of the "greenhouse" gases - the most sophisticated of models cannot predict global response accurately. Research is improving our ability to develop more accurate estimates of ecological effects, but it will be many years before we can develop enough understanding to know how human interventions may perturb the present state of global or regional ecological systems. We do not know how stable (or unstable) B.C. ecological systems are, that is, how sensitive they are to changes in air quality or to development, generally. Most importantly, these issues ought to suggest that flexible planning and environmental management which take into account new concepts and data as they appear should be given high priority.

The review raises a number of questions respecting environmental sustainability in British Columbia. These may be framed as follows.

- Do we need airshed ambient standards and target loadings to know when we are achieving sustainability?

- Do we need more up-to-date emission standards, and more comprehensive proponent data, so that proposed developments may be thoroughly assessed?

- Do we need regional air management authorities to deal with air quality management in large-scale airsheds?

- Do we have adequate processes and policies for dealing with current problems, such as wood waste burners and regional ozone, which may serve as models for the future?

- Should B.C. develop a strategy for preventing significant deterioration of existing air quality in areas of the province which are undeveloped or developing?

- Should B. C. lead the way in managing emissions which contribute to global problems, or should we participate as required in national programs?

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